PROCESSOR BASED SIGNAL AND TRAIN CONTROL SYSTEMS
ALTERNATE BASE CASE ISSUE

How did we get to this issue:

In the Processor Based Signal and Train Control Systems Notice of Proposed Rulemaking (NPRM) The Federal Railroad Administration (FRA) proposed a performance based regulatory scheme, based on the Rail Safety Advisory Committee (RSAC), Positive Train Control Working Group's (working group) recommendations. The essence of that standard is the railroad could adopt any signal and train control system as long as it could show that total safety would not be worse after adoption of the new system. The working group adopted the standard because most experts agreed that the current toolset for evaluating risk was best suited to comparative risk assessment, and that any standard based on another approach, such as absolute level of risk, would be very difficult to implement. FRA agreed, but wanted to ensure that safety would not diminish from what it would otherwise be in those cases where the railroad was adopting a new signal and train control system at the same time as it was increasing the speed or frequency of its operations.

For those cases in which the railroad was going to increase train speed or density, the FRA wanted to adjust the base case in the comparison to a level that would be expected were the railroad to increase speed or frequency under current regulations. The working group agreed and a provision for an adjusted base case became part of the NPRM. During the comment period for the NPRM, the Association of American Railroads (AAR) took issue with the particular language implementing the adjusted base case. The AAR comment is attached as a reference. After much discussion with RSAC participants, the working group decided to form a task force, known as the risk 2 team, to address this issue and other issues. In its initial meetings the risk 2 team agreed on some adjustments to the base case, but only where speed changes would be involved. In particular the group agreed that the base case should be adjusted where the speed crossed a threshold now in effect under section 236.0. The risk 2 team initially could not agree on adjustments based on train frequency.

What were the factual issues?

The AAR initially maintained that risk did not go up with train frequency, that instead it appears to go down, so there was not good reason to adjust the base case. FRA maintained that risk increased with train frequency. Both FRA and AAR agreed that for any system, the risk would tend to increase with train speed. FRA undertook to research the issue, through the Volpe National Transportation Center and other contractors. FRA presented the research to the risk 2 team, which agreed on the following:

> Risk per train mile in dark territory is approx 2 times the risk of other territories, TCS, ABS, and Auto.
>
> Risk doesn't change much with increased speed or frequency in CTC, ABS and Auto.
>
> Risk in dark territory does increase with speed and/or frequency.

The cost per mile of risk from positive train control preventable accidents is about 12 cents in dark territory and is about 6 cents per train mile elsewhere.

These facts were based only on analysis of freight operations and excluded any passenger trains or accidents from risk metrics.

FRA also presented evidence that operations with more than 16 trains over day in dark territory were extremely rare, and operations with more than 20 trains per day in dark territory were almost nonexistent.

Why we need an adjusted base case:

FRA believes that some of the new systems being proposed might make it possible to run more than 20 trains per day in what is now dark territory, but might not provide the level of safety now provided by TCS (that is, it's close enough it should be demonstrated). The risk 2 team discussed adopting TCS as a minimum base case, but rejected the idea, even though it is unlikely a Class I railroad would adopt a system that was not at least as safe as TCS, because the railroad would want to propagate that system throughout its lines. There might be short lines somewhere which could enhance safety by adopting a system which was safer than dark territory but not as safe as TCS, and that those short lines would not be likely to increase traffic to the point where the adjusted base case was triggered.

The risk 2 team agreed that an adjusted base case was appropriate when the level of traffic increased to where the railroad would now adopt TCS. This included increases in speed which more than doubled the current speed limit and which result in a speed limit in excess of 40 mph. In practice this means a speed limit of 20 mph or less being raised to 45 mph, for those cases in which speed limits are multiples of 5 mph. Any speed of 25 mph or more which doubles would have triggered the speed in section 236.0. The group also agreed that increasing the number of trains per day by more than five trains per day, to a frequency of more than 15 trains per day, would be a reasonable ground for using the adjusted base case. The group agreed to provide additional latitude for unexpected traffic increases after three years, so that the trigger would not be reached until frequency exceed 20 trains per day. Further, the group agreed that trains per day would be an annual average, which means that seasonal or weekly variations could yield short term flows well in excess of the trigger without require an adjusted base case.

Last, the risk 2 team was concerned that passenger operations are seldom conducted on a large scale without the protection of signals. The group agreed that if the number of passenger trains increased by more than 2 trains per day, the adjusted base case would be TCS. The risk 2 team agreed to seek the counsel of passenger railroads, none of which were at the meeting, before the next working group meeting.

Generalization of risk assessment results

The risk 2 team addressed two other issues, the risk metric, as discussed below, and generalization. The railroads were concerned that they be able to use results from one risk assessment to reduce the effort required to assess the risk when a processor based signal and train control system already in use under the NPRM was propagated into another territory. FRA sought advice from the risk 2 team, and agreed that FRA would draft language to put into the preamble of the final rule which would make it clear that FRA would accept generalized risk assessments under conditions which were likely to convince FRA that the risk was likely not to increase when the system was to propagate. The consensus on generalization was key in getting consensus on adjusted base case issues.

Risk Metric

FRA asked the group to recommend altering the proposed risk metric. In the NPRM risk is measured in severity divided by exposure. Severity is measured in total societal cost of affected accidents, or at the railroad's discretion total fatalities due to affected accidents. The exposure is measured two ways: train-miles and passenger-miles, where there are passengers. This results in an appropriate metric, total societal risk per train mile, and a metric that doesn't make as much sense, total societal risk per passenger mile. If passenger mile predictions are off, this metric can be very strange. In place of the second metric, FRA asked the group to adopt a metric where the severity is total societal cost of passenger injuries and fatalities and the exposure is passenger miles.

What do we need now:

There were no passenger railroads represented directly at the risk 2 team, so we need to gain consensus from passenger railroads on the risk 2 team issues. We have contacted American Public Transportation Association and Amtrak, and have explained the events so far to them.

What does it take to trigger the adjusted base case by virtue of increased passenger train frequency?

1-The railroad must be installing a processor based signal and train control system.
2-The current system must be dark territory.
3-The current speed must be less than 50 mph.
4-The proposed speed must be less than 50 mph.
5-If the proposed speed is more than 40 mph, the previous speed must be more than half the proposed speed.
6-The proposed traffic must not be increasing by more than 5 trains per day to a total frequency of more than 15 trains per day.
7-The proposed traffic must be increasing by more than 730 passenger trains per year.

Further, the adjusted base case will not have any adverse effect on a railroad if the new signal and train control system is at least as safe as TCS. FRA believes it is extremely unlikely that any railroad would expose itself to the liability it might incur if it were to adopt a marginally safe

system where passengers are involved. FRA does not believe such occurrences will be common, if they will ever occur at all, although FRA does not want to see significant increases in passenger train frequency without providing the protection equivalent to TCS. It does not appear that this provision will ever affect any operation, but FRA believes that were it to be an issue, the requirement is appropriate.

AMTRAK/APTA SUGGESTED MODIFICATION:

In order to make it easier to expand service, Amtrak has requested, and apparently APTA supports, a modification to the language established by the risk 2 team which would change the third trigger from an increase of more than two passenger trains per day, to an increase of more than four passenger trains per day. FRA is willing to accept this suggestion.

For Office of Safety, Federal Railroad Administration
RSAC/PTC Working Group Risk 2 Team

Base Case Risk Assessment: Data Analysis & Tests

By Railroad Systems Division (DTS-75)
Office of Safety and Security
The John Volpe National Transportation Systems Center

U.S. Department of Transportation
Research and Special Programs Administration

Base Case Risk Assessment:
Probability and Consequence Analysis of PPA Risks

Presentation Version

Updated on April 21, 2003

U.S. Department of Transportation
Research and Special Programs Administration

Table of Contents

Terms and Definitions

- PTC: Positive Train Control
- PPA: PTC Preventable Accident
- SPEED: Speed Limit or Maximum Allowed Speed
- ADTC: Average Daily Train Count (2-way volume)
- AATC: Average Annual Train Count (2-way volume)
- Link: A graphic line representing one or multiple tracks between two points
- Train-Miles: Average Annual 2-Way Train-Miles
  - as: (ADTC) * (Link-Miles)
- RISK: PPA Cost Per Train-Mile
  - as: (Annual PPA Cost) / (Annual Train-Miles)

Functional Objectives

- To summarize the "current level of risk" for each territory, speed class and train frequency
  - Calculate the weighted average of "all mainline railroad segments"
- To test the following conjectures:
  - When speed increases, the risk increases
  - When train frequency (ADTC) increases, the risk increases
  - The general risk level is in ascending order from Auto, CTC, ABS, then to Dark territory

Train-Mile Statistics

Total Train-Miles for PPA-segments:
Sum: 73045719.696
Count: 489
Mean: 149377.750
Maximum: 2634465.604
Minimum: 66.880
Range: 2634398.725
Variance: 84387759701.519
Standard Deviation: 290495.714

PPA-segment TM is 15.09%

Train-Miles for All segments:
Sum: 484,175,546.802
Count: 12432
Mean: 38945.909
Maximum: 2634465.604
Minimum: 4.648
Range: 2634460.956
Variance: 10749782887.936
Standard Deviation: 103681.160

TRAINMILES by Territory:

AUTO: 44,220,891
CTC: 300,580,358
ABS: 80,773,696
DARK: 58,600,600

Total Train-Miles: 484,175,547

PPA & RISK Statistics

PPA (1988-1997):

Frequency: 535
On 489 Railroad Segments

Total Costs (1988-1997):

ALL:	346,215,890
AUTO:	24,070,867
CTC:	202,892,177
ABS:	47,671,575
DARK:	71,581,271

Average RISK by Territory

PPA Cost/Train-Mile:
ALL: 0.071506273

AUTO: 0.054433247
CTC: 0.067500145
ABS: 0.059018687
DARK: 0.122151088

Segment Risk Statistics

RISK/TM for PPA-segments:
Count: 489
Mean: 3.339697
Maximum: 206.821750
Minimum: 0.000549
Range: 206.821201
Variance: 237.071000
Standard Deviation: 15.397110

Average Risk: 0.473971495

RISK/TM for all segments:
Count: 12432
Mean: 0.131364
Maximum: 206.821750
Minimum: 0.000000
Range: 206.821750
Variance: 9.728117
Standard Deviation: 3.118993

Average Risk: 0.071506273

Multiple Regression

Multiple Regression of the Log Values: Anti-Log MR

Log(RISK) = a* Log(SPEED) + b* Log(ADTC)+ c

RISK = 10^(a* Log(SPEED) + b* Log(ADTC)+ c)

To deal with zero-value's log, add weight (w) is added:

Log(RISK+w) = a* Log(SPEED) + b* Log(ADTC)+ c

RISK = 10^(a* Log(SPEED) + b* Log(ADTC)+ c)

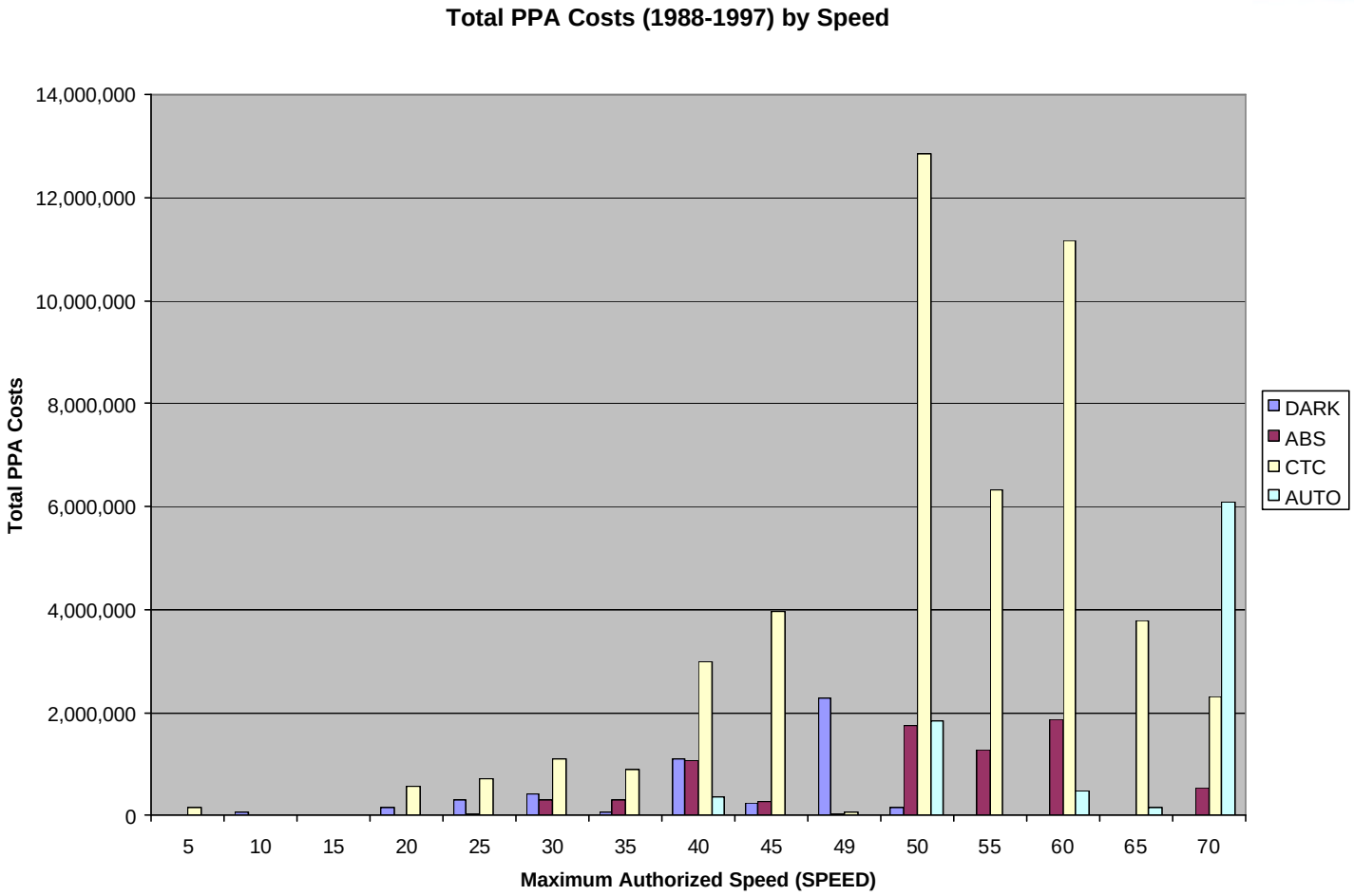
- W is the average risk per train-mile or other values.
- The formula will generate smooth curve-lines for RISK (y) in both SPEED (x1) and ADTC (x2).

Data Statistics

Including Zero-Value Segments. Assign a RISK value to no-PPA segments

Total PPA Cost by Speed

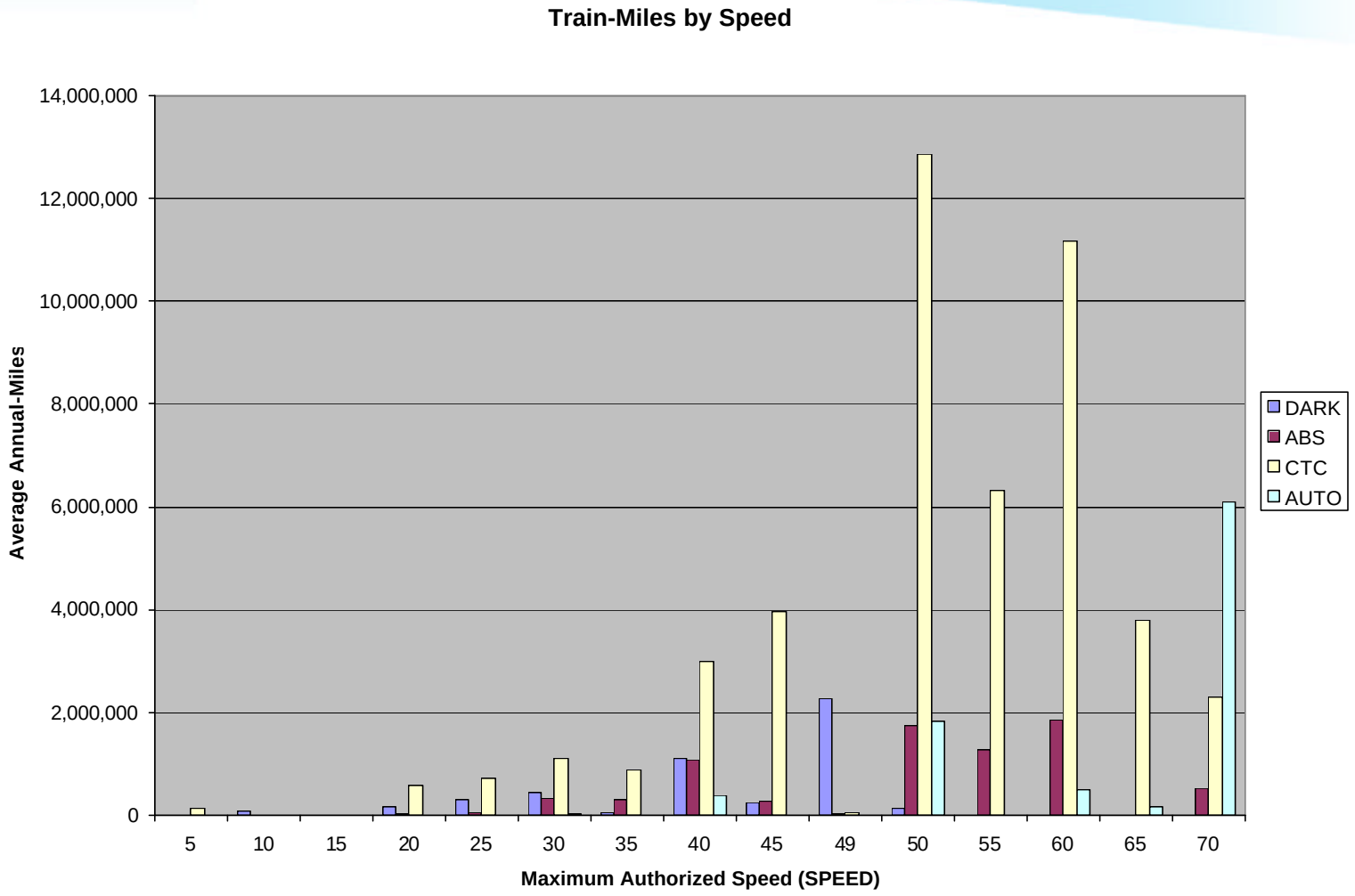
Overlay RAIRS data on top of Volpe Rail Network (VRN)



Train-Miles by Speed

Volpe Rail Network (VRN)

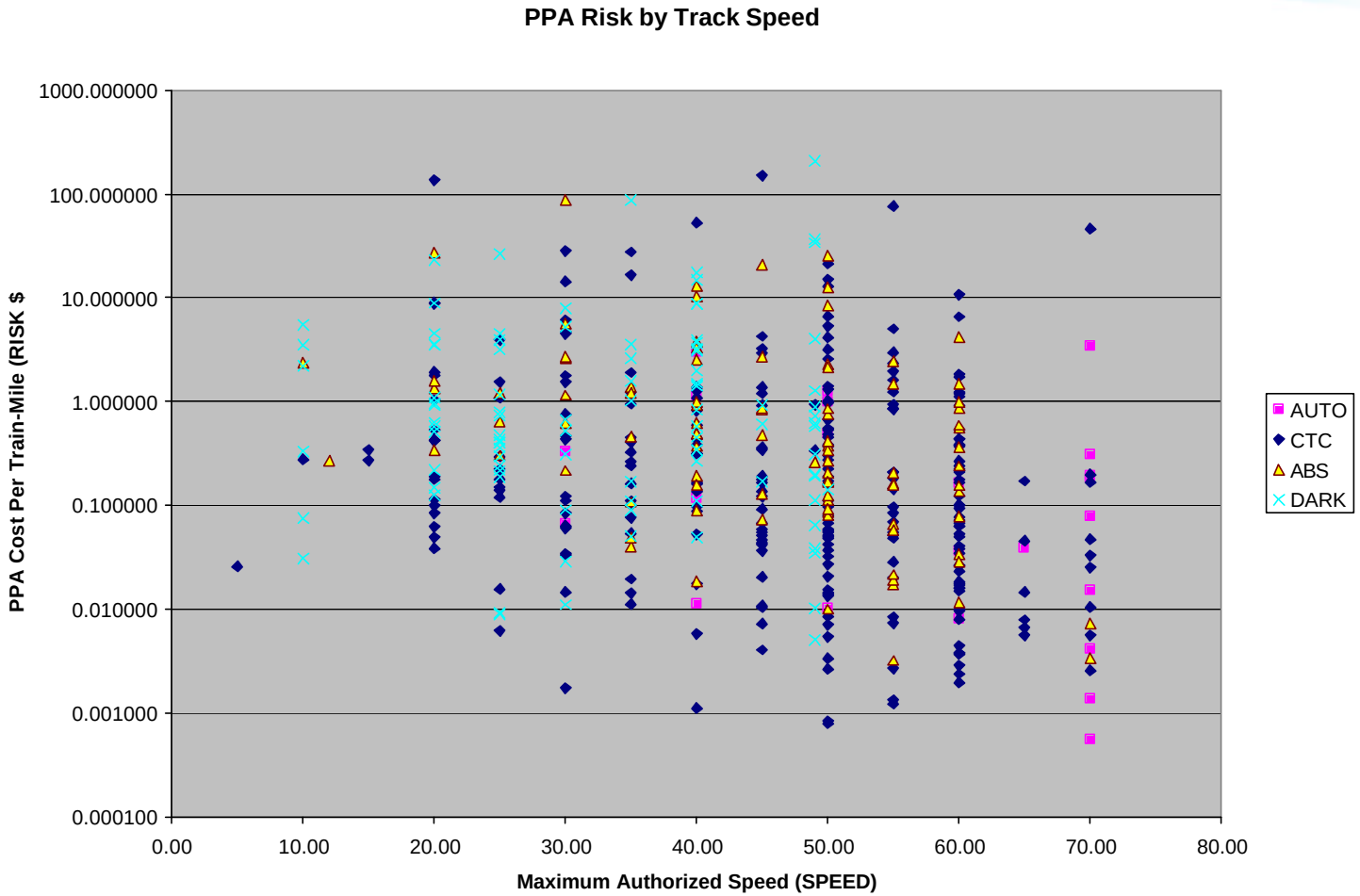
AADT/ADTC: Average Daily Train Count



RISK/TM by Speed

PPA RISK/Train-Mile by Maximum Authorized Speed (MAS or Speed Class

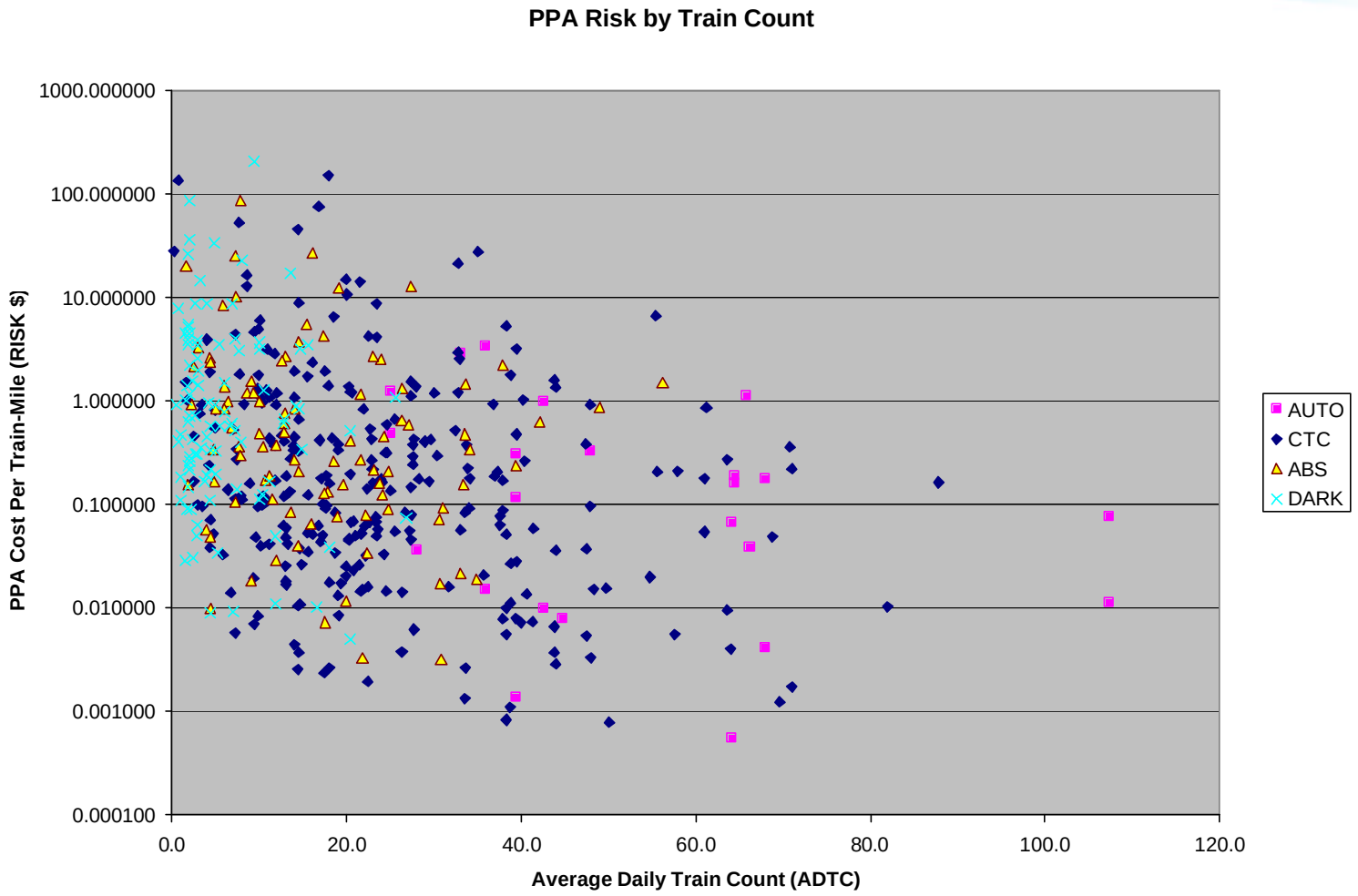
(Logarithmic Scale)



RISK/TM by ADTC

PPA Risk/Train-Mile by Average Daily Train Count (ADTC/AADT)

(Logarithmic Scale)



Model All Segments

Including Zero-Value Segments. Assign a RISK value to no-PPA segments

Linear MR: Coefficients

1) Linear Multiple Regression: ALL Territory

Linear	Slope a	Slope b	Intercept c	Standard I for RISK	Statistics RSQ	Statistics F
DARK	0.010928	0.004216	-0.185857	0.147594	0.001418	2.9010545
ABS	-0.001557	-0.001642	0.199726	0.132762	0.000228	0.2704723
CTC	-0.00068	-0.002859	0.222008	0.141859	0.000194	0.540058
AUTO	0.000844	0.0001	-0.012263	0.041225	0.003018	0.5872278
ALL	0.002202	-0.002237	0.079705	0.075652	0.000153	0.9535561

1) Negative Slopes (a, b) in CTC and ABS
2) Positive Slopes (a, b) in DARK and AUTO
3) Positive Slope a and Negative Slope b in ALL

Anti-Log MR: Coefficients

2) Anti-Log Multiple Regression: ALL Territory Including all segments

Anti-Log	Slope	Slope	Intercept	Standard I	Statistics	Statistics
	a	b	c	for RISK	RSQ	F
DARK	0.039447	0.011929	-0.946347	0.01997	0.003221	6.5993432
ABS	0.024132	0.020358	-1.247969	0.040552	0.001921	2.2797998
CTC	0.01344	0.006849	-1.166033	0.026748	0.000325	0.9056158
AUTO	0.059005	0.034398	-1.370616	0.087125	0.012963	2.5479315
ALL	0.024441	0.006153	-1.154911	0.014496	0.001092	6.7916258

- Added the ALL average risk (w) to no-PPA segments
- Positive Slopes (a, b) in all models

Mean Value Tests:

Sensitivity Tests on All Territory:

When SPEED=40 and TRAIN=40

Linear Multiple Regression:

- Linear (including 0): RISK =0.07831879

Anti-Log Multiple Regression: add different w values

1) Add an average risk 0.071506273: RISK = 0.078361380
2) Add a mean risk 0.131364: RISK =0.141546594
3) Add a minimum risk $1/10^8$: RISK = 0.000000019
4) Add 1: RISK = 0.027187413

Best approximation comes from average risk

Anti-Log Multiple Regression

Anti-Log	Slope	Slope	Intercept	Standard E	Statistics	Statistics
	a	b	c	for RISK	RSQ	F
DARK	0.039447	0.011929	-0.946347	0.01997	0.003221	6.599343
ABS	0.024132	0.020358	-1.247969	0.040552	0.001921	2.2798
CTC	0.01344	0.006849	-1.166033	0.026748	0.000325	0.905616
AUTO	0.059005	0.034398	-1.370616	0.087125	0.012963	2.547931
ALL	0.024441	0.006153	-1.154911	0.014496	0.001092	6.791626

Add the territory average RISK (w) for the no-PPA segments

RISK = 10^(a*LOG(SPEED)+b*LOG(ADTC)+c)

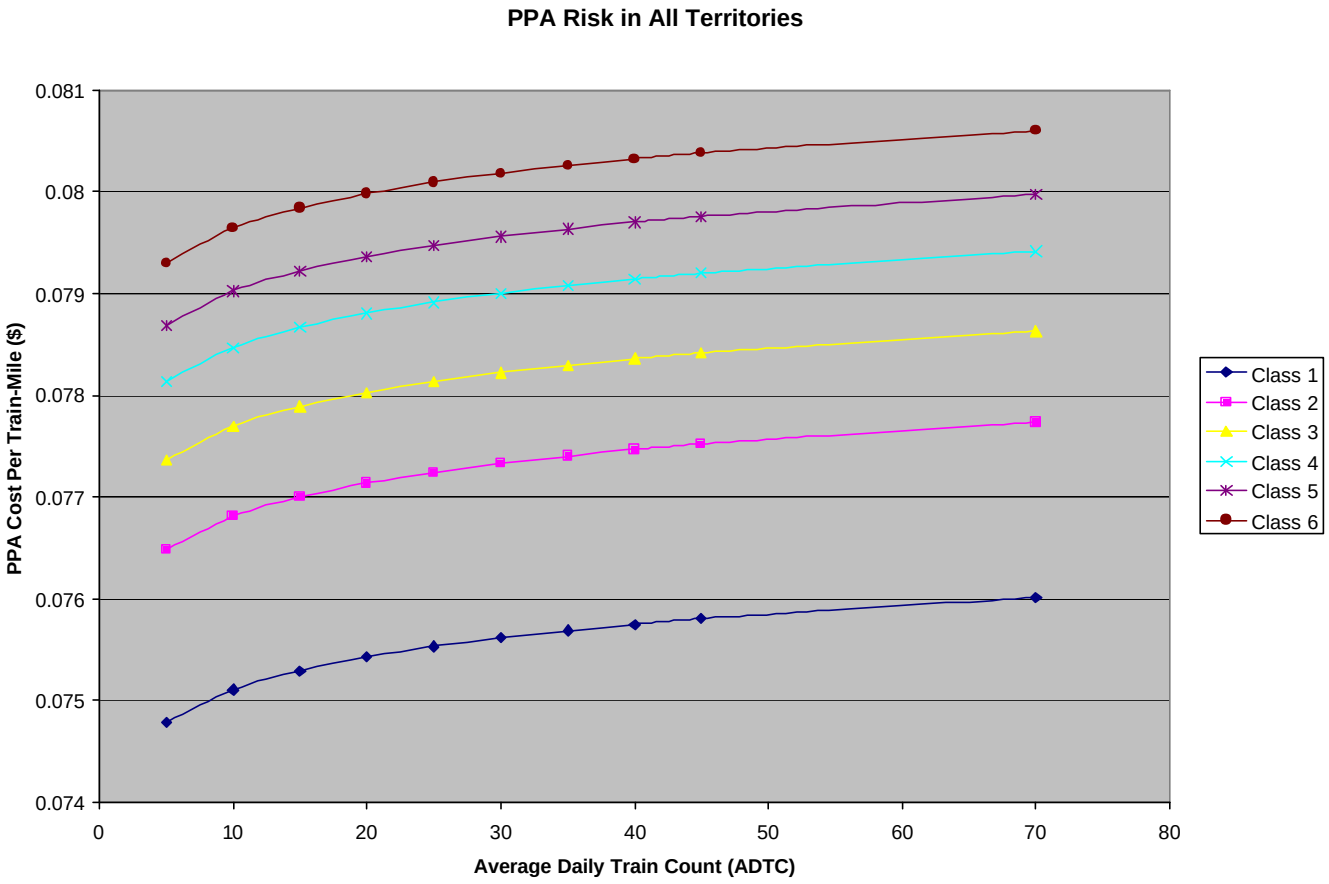
RISK/TM by ADTC for ALL

All Territories (ALL):
(Logarithmic Scale)

PPA Risk per Train-Mile by Average Daily Train Counts (ADTC/AADT) and by Speed Classes

RISK = 10^(0.024440857
* Log(SPEED) +0.006153083
* Log(ADTC) -1.154911256)

Where W= 0.071506273
(ALL Average Risk)



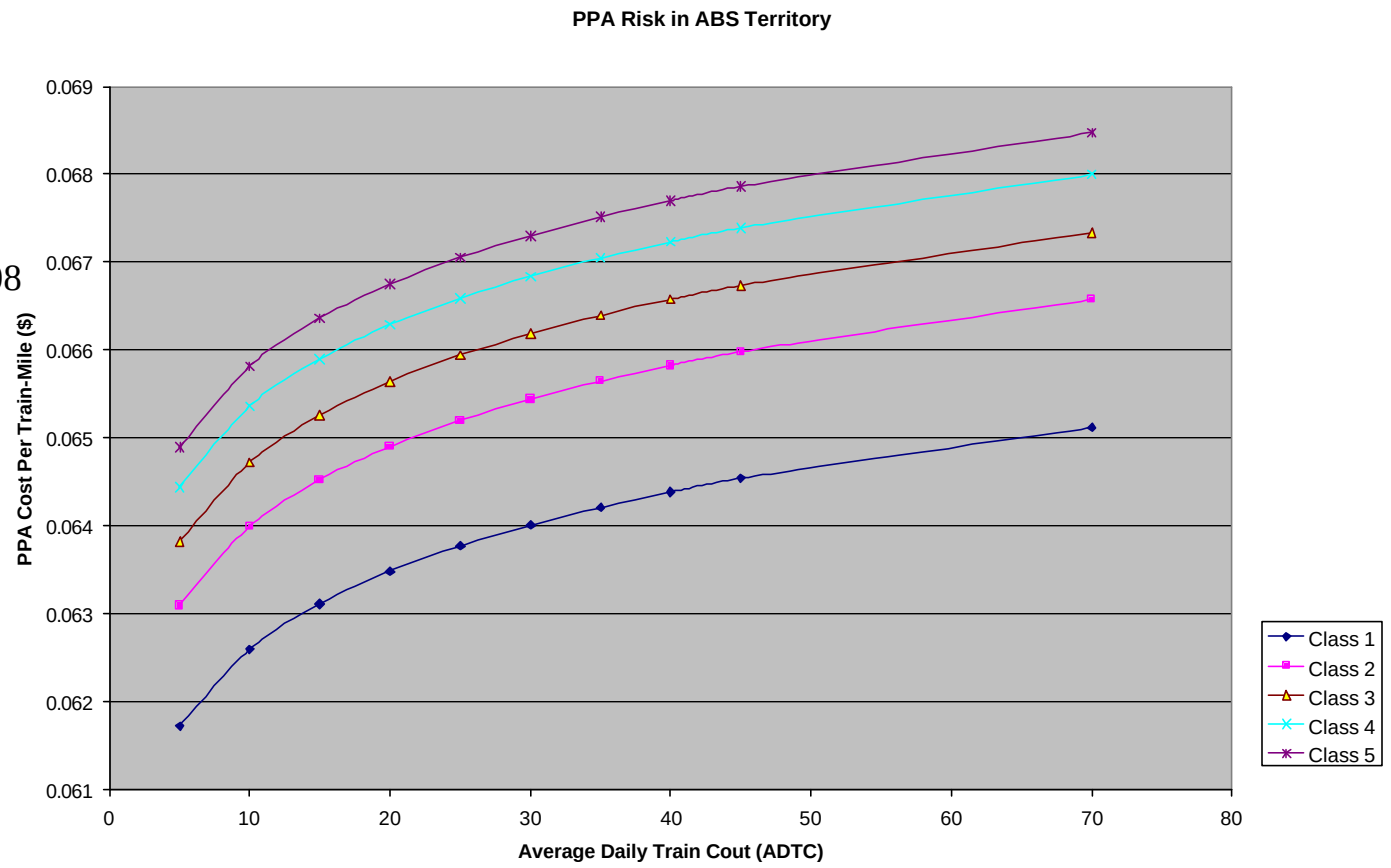
RISK/TM by ADTC for DARK

DARK Territory (DARK):
(Logarithmic Scale)

PPA Risk per Train-Mile by Average Daily Train Counts (ADTC/AADT) and by Speed Classes

RISK = 10^(0.039446971
* Log(SPEED) +0.011929008
* Log(ADTC) -0.946347175
)

Where W=0.122151088
(DARK Average Risk)



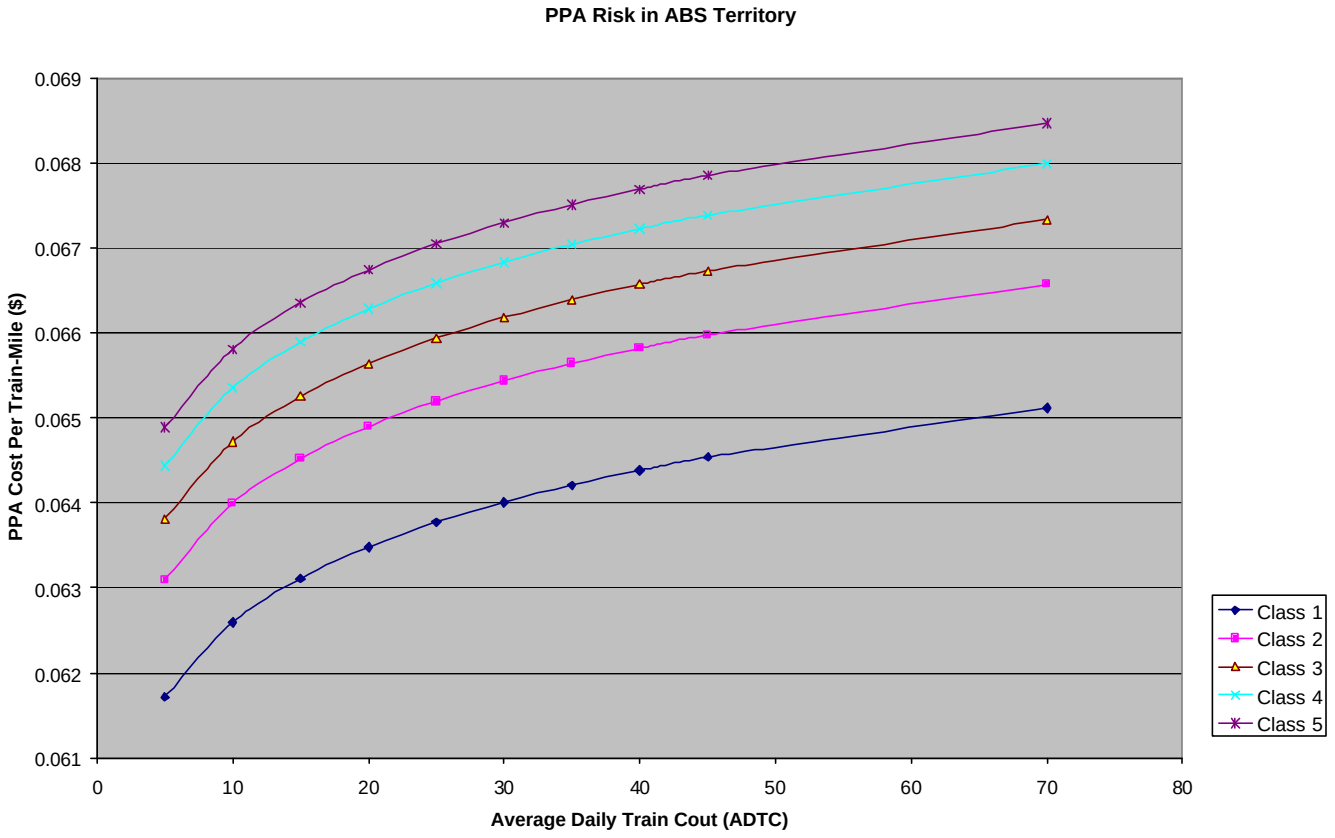
RISK/TM by ADTC for ABS

Automatic Block System Territory (ABS):
(Logarithmic Scale)

PPA Risk per Train-Mile by Average Daily Train Counts (ADTC/AADT) and by Speed Classes

RISK = 10^(0.024131854 * Log(SPEED) +0.020358476 * Log(ADTC) -1.247969024)

Where W=0.059018687 (ABS Average Risk)



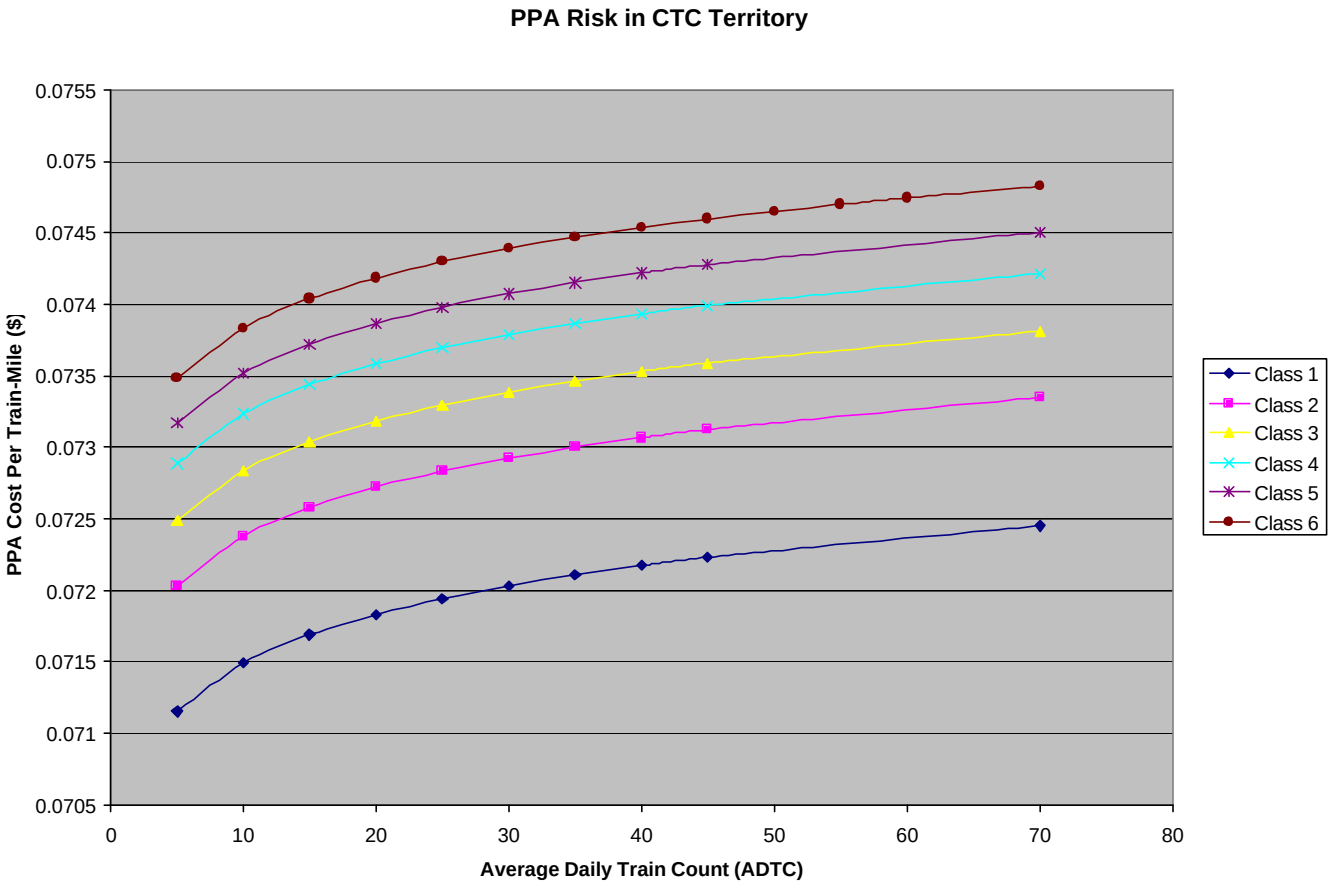
RISK/TM by ADTC for CTC

Centralized Train Control Territories (CTC):
(Logarithmic Scale)

PPA Risk per Train-Mile by Average Daily Train Counts (ADTC/AADT) and by Speed Classes

RISK = 10^(0.013439943 * Log(SPEED) +0.00684885 * Log(ADTC) -1.166032656)

Where W=0.067500145 (CTC Average Risk)



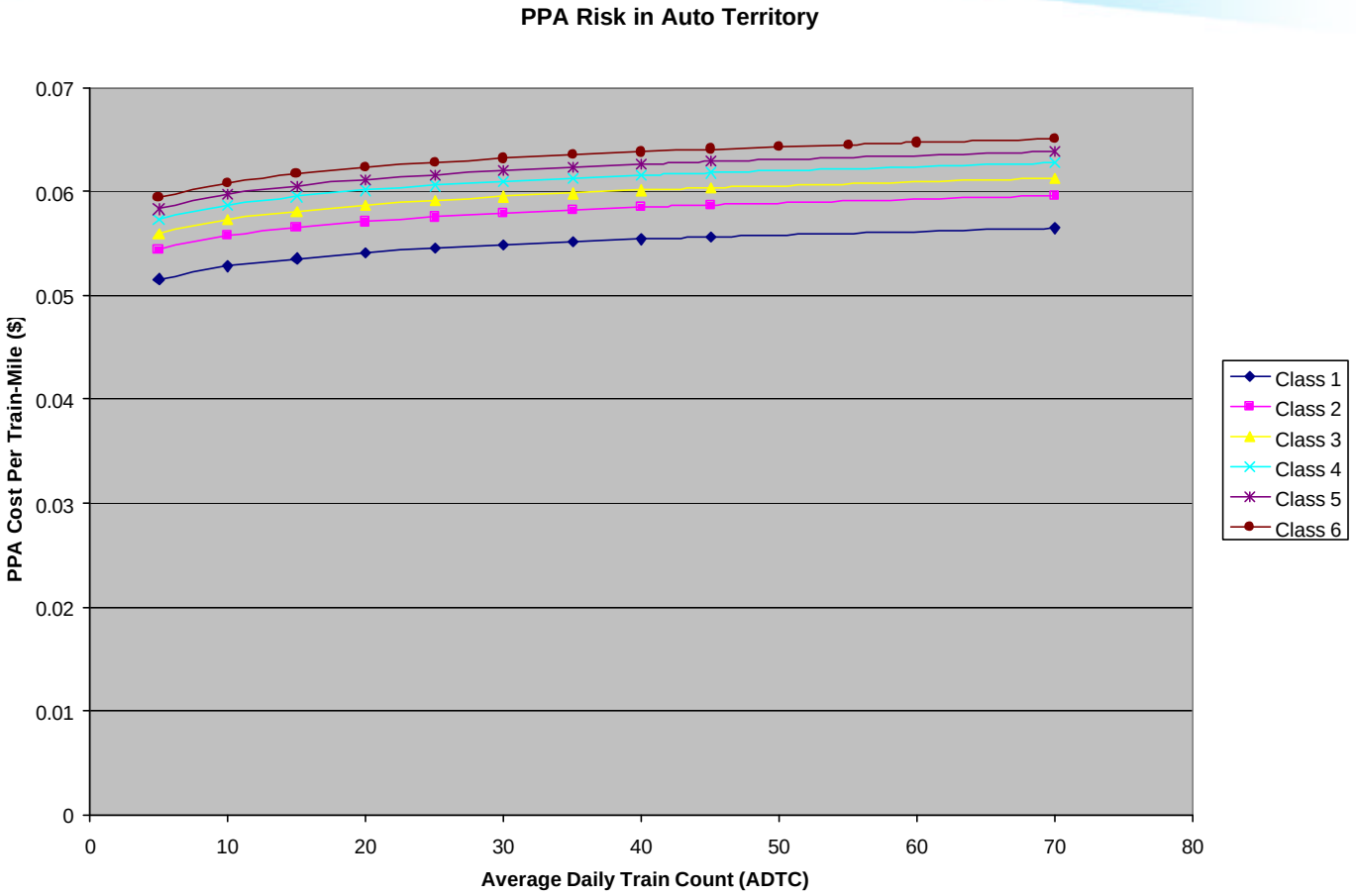
RISK/TM by ADTC for AUTO

Automatic (Cab Signal) Territories (AUTO):
(Logarithmic Scale)

PPA Risk per Train-Mile by Average Daily Train Counts (ADTC/AADT) and by Speed Classes

RISK = 10^(0.024440857 * Log(SPEED) +0.006153083 * Log(ADTC) -1.154911256)

Where W= 0.054433247 (AUTO Average Risk)



RISK for ALL Territory

Note:

- Anti-Log MR:
- With the average RISK for all segment added

SPEED	Class 1	2	3	4	5	6	Mean
AADT	**10**	**25**	**40**	**60**	**80**	**110**	**45**
5	0.07478774	0.076482	0.077365	0.078136	0.078687	0.079302	0.07745979
10	0.07510739	0.076808	0.077696	0.07847	0.079023	0.079641	0.077790861
15	0.07529501	0.077	0.07789	0.078666	0.079221	0.07984	0.077985181
20	0.07542841	0.077137	0.078028	0.078805	0.079361	0.079981	0.078123347
25	0.07553204	0.077243	0.078135	0.078913	0.07947	0.080091	0.078230686
30	0.07561683	0.077329	0.078223	0.079002	0.079559	0.080181	0.078318497
35	0.07568858	0.077403	0.078297	0.079077	0.079635	0.080257	0.078392818
40	0.0757508	0.077466	0.078361	0.079142	0.0797	0.080323	0.078457254
45	0.07580572	0.077523	0.078418	0.079199	0.079758	0.080381	0.078514135
70	0.07601208	0.077734	0.078632	0.079415	0.079975	0.0806	0.078727877

ALL	**Slope**	**Slope**	**Intercept**	**Standard Error**	**Statistics**	**Statistics**
	a	**b**	**c**	**for RISK**	**RSQ**	**F**
Linear	0.002202478	-0.002237129	0.079704824	0.075652073	0.000153417	0.953556
Anti-Log	0.024440857	0.006153083	-1.154911256	0.014495815	0.001091675	6.791626

* The positive slopes in the models show that the RISK increase when the SPEED or TRAIN COUNT increases.

RISK for DARK Territory

Note:

- Anti-Log MR:
- With the average RISK for all dark segments added

SPEED	Class 1	2	3	4	Mean
AADT	10	25	40	49	27
5	0.12631	0.130959	0.13341	0.13448194	0.1312902
10	0.127359	0.132046	0.134517	0.13559852	0.1323802
15	0.127976	0.132687	0.13517	0.13625597	0.1330221
20	0.128416	0.133143	0.135634	0.13672437	0.1334794
25	0.128758	0.133498	0.135996	0.1370888	0.1338351
30	0.129039	0.133788	0.136292	0.13738728	0.1341265
35	0.129276	0.134034	0.136543	0.13764015	0.1343734
40	0.129482	0.134248	0.13676	0.13785957	0.1345876
45	0.129664	0.134437	0.136953	0.13805341	0.1347769

DARK	Slope a	Slope b	Intercept c	Standard Error for RISK	Statistics RSQ	Statistics F
Linear	0.010928393	0.004216201	-0.185856795	0.147593795	0.00141833	2.9010545
AntiLog	0.039446971	0.011929008	-0.946347175	0.019969899	0.003220607	6.5993432

* The positive slopes in the models show that the RISK increase when the SPEED or TRAIN COUNT increases.

RISK for ABS Territory

Note:

- Anti-Log MR:
- With the average RISK for ABS segments added

SPEED	Class 1	2	3	4	Mean
AADT	**10**	**25**	**40**	**60**	**40**
5	0.061715	0.063095	0.063815	0.064442	0.063815
10	0.062592	0.063992	0.064722	0.065358	0.064722
15	0.063111	0.064522	0.065258	0.0659	0.065258
20	0.063482	0.064901	0.065642	0.066287	0.065642
25	0.063771	0.065197	0.06594	0.066589	0.06594
30	0.064008	0.065439	0.066186	0.066836	0.066186
35	0.064209	0.065645	0.066394	0.067046	0.066394
40	0.064384	0.065824	0.066574	0.067229	0.066574
45	0.064539	0.065982	0.066734	0.06739	0.066734
70	0.065122	0.066578	0.067337	0.067999	0.067337

ABS	Slope a	Slope b	Intercept c	Standard Error for RISK	Statistics RSQ	Statistics F
Linear	-0.001557018	-0.001641569	0.199726113	0.132761554	0.000228291	0.270472
Anti-Log	0.024131854	0.020358476	-1.247969024	0.040551969	0.001920997	2.2798

* The positive slopes in the models show that the RISK increase when the SPEED or TRAIN COUNT increases.

RISK for CTC Territory

Note:

- Anti-Log MR:
- With the average RISK for CTC segments added

SPEED	Class 1	2	3	4	5	6	Mean
AADT	**10**	**25**	**40**	**60**	**80**	**110**	**40**
5	0.071153	0.072035	0.072491	0.072887	0.073170	0.073484	0.072491
10	0.071492	0.072378	0.072836	0.073234	0.073518	0.073833	0.072836
15	0.071691	0.072579	0.073039	0.073438	0.073722	0.074039	0.073039
20	0.071832	0.072722	0.073183	0.073583	0.073868	0.074185	0.073183
25	0.071942	0.072833	0.073295	0.073695	0.073981	0.074298	0.073295
30	0.072032	0.072924	0.073386	0.073787	0.074073	0.074391	0.073386
35	0.072108	0.073001	0.073464	0.073865	0.074151	0.074470	0.073464
40	0.072174	0.073068	0.073531	0.073933	0.074219	0.074538	0.073531
45	0.072232	0.073127	0.073590	0.073993	0.074279	0.074598	0.073590
70	0.072451	0.073349	0.073813	0.074217	0.074504	0.074652	0.073813

CTC	Slope	Slope	Intercept	Standard Error	Statistics	Statistics
	a	b	c	for RISK	RSQ	F
Linear	-0.00068044	-0.002859397	0.222008449	0.141859352	0.000193601	0.540058
Anti-Log	0.013439943	0.00684885	-1.166032656	0.026747673	0.000324604	0.9056158

* The positive slopes in the models show that the RISK increase when the SPEED or TRAIN COUNT increases.

RISK for AUTO Territory

Note:

- Anti-Log MR:
- With the average RISK for auto segments added

SPEED	Class 1	2	3	4	5	6	Mean
AADT	**10**	**25**	**40**	**60**	**80**	**110**	**45**
5	0.051574	0.054439	0.05597	0.057326	0.058307	0.059413	0.056171557
10	0.052819	0.055753	0.057321	0.058709	0.059714	0.060847	0.057526948
15	0.053561	0.056536	0.058126	0.059533	0.060553	0.061701	0.058334912
20	0.054093	0.057098	0.058704	0.060125	0.061155	0.062315	0.058915044
25	0.05451	0.057538	0.059156	0.060589	0.061626	0.062795	0.059369
30	0.054853	0.0579	0.059528	0.06097	0.062014	0.06319	0.059742504
35	0.055145	0.058208	0.059845	0.061294	0.062343	0.063526	0.06006013
40	0.055398	0.058476	0.06012	0.061576	0.06263	0.063818	0.060336635
45	0.055623	0.058713	0.060365	0.061826	0.062885	0.064077	0.060581585
70	0.056475	0.059613	0.061289	0.062773	0.063848	0.06431	0.061384575

AUTO	Slope a	Slope b	Intercept c	Standard Error for RISK	Statistics RSQ	Statistics F
Linear	0.000843556	0.000100075	-0.012263466	0.041225219	0.003017813	0.5872278
Anti-Log	0.059005404	0.034398145	-1.370615736	0.087124818	0.01296341	2.5479315

* The positive slopes shows that the RISK increases when the SPEED or TRAIN COUNT increases.

RISK for ALL Territory

SPEED	Class 1	2	3	4	5	6	Mean
AADT	**10**	**25**	**40**	**60**	**80**	**110**	**45**
5	0.07478774	0.076482	0.077365	0.078136	0.078687	0.079302	0.07745979
10	0.07510739	0.076808	0.077696	0.07847	0.079023	0.079641	0.077790861
15	0.07529501	0.077	0.07789	0.078666	0.079221	0.07984	0.077985181
20	0.07542841	0.077137	0.078028	0.078805	0.079361	0.079981	0.078123347
25	0.07553204	0.077243	0.078135	0.078913	0.07947	0.080091	0.078230686
30	0.07561683	0.077329	0.078223	0.079002	0.079559	0.080181	0.078318497
35	0.07568858	0.077403	0.078297	0.079077	0.079635	0.080257	0.078392818
40	0.0757508	0.077466	0.078361	0.079142	0.0797	0.080323	0.078457254
45	0.07580572	0.077523	0.078418	0.079199	0.079758	0.080381	0.078514135
70	0.07601208	0.077734	0.078632	0.079415	0.079975	0.0806	0.078727877

Note:

- Anti-Log MR:
- With the average RISK for all segments added

ALL	Slope a	Slope b	Intercept c	Standard Error for RISK	Statistics RSQ	Statistics F
Linear	0.002202478	-0.002237129	0.079704824	0.075652073	0.000153417	0.953556
Anti-Log	0.024440857	0.006153083	-1.154911256	0.014495815	0.001091675	6.791626

* The positive slopes in the models show that the RISK increase when the SPEED or TRAIN COUNT increases.

Linear Multiple Regression:

Linear	Slope	Slope	Intercept	Standard I	Statistics	Statistics
	a	b	c	for RISK	RSQ	F
DARK	0.010928	0.004216	-0.185857	0.147594	0.001418	2.901054
ABS	-0.001557	-0.001642	0.199726	0.132762	0.000228	0.270472
CTC	-0.00068	-0.002859	0.222008	0.141859	0.000194	0.540058
AUTO	0.000844	0.0001	-0.012263	0.041225	0.003018	0.587228
ALL	0.002202	-0.002237	0.079705	0.075652	0.000153	0.953556

Model all segments including zero-risk segments

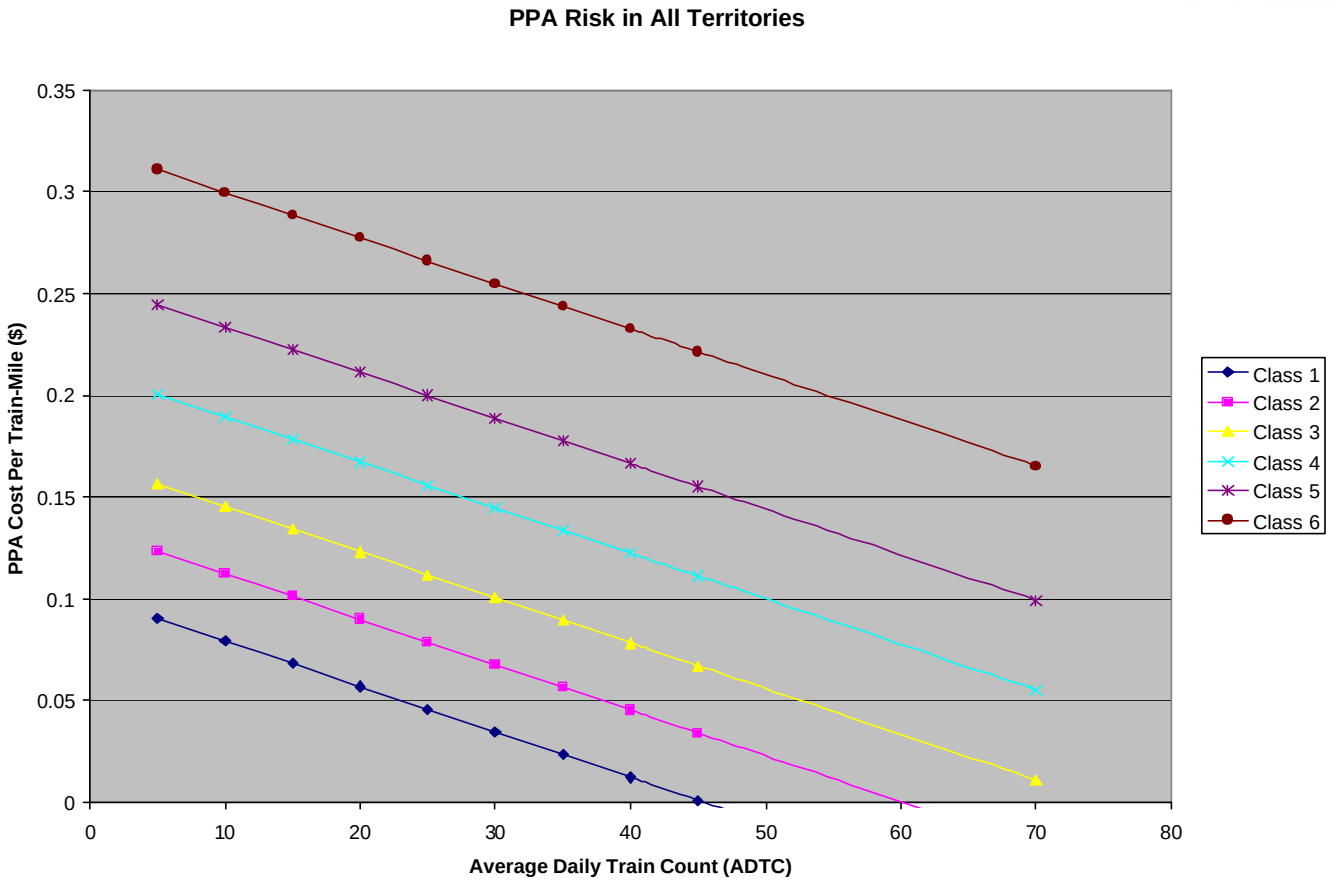
RISK= a*(SPEED)+ b*(ADTC)+ c

RISK/TM by ADTC for ALL

All Territories (ALL):

PPA Risk per Train-Mile by Average Daily Train Counts (ADTC/AADT) and by Speed Classes

RISK = 0.002202478
* (SPEED) -0.002237129
* (ADTC) +0.079704824

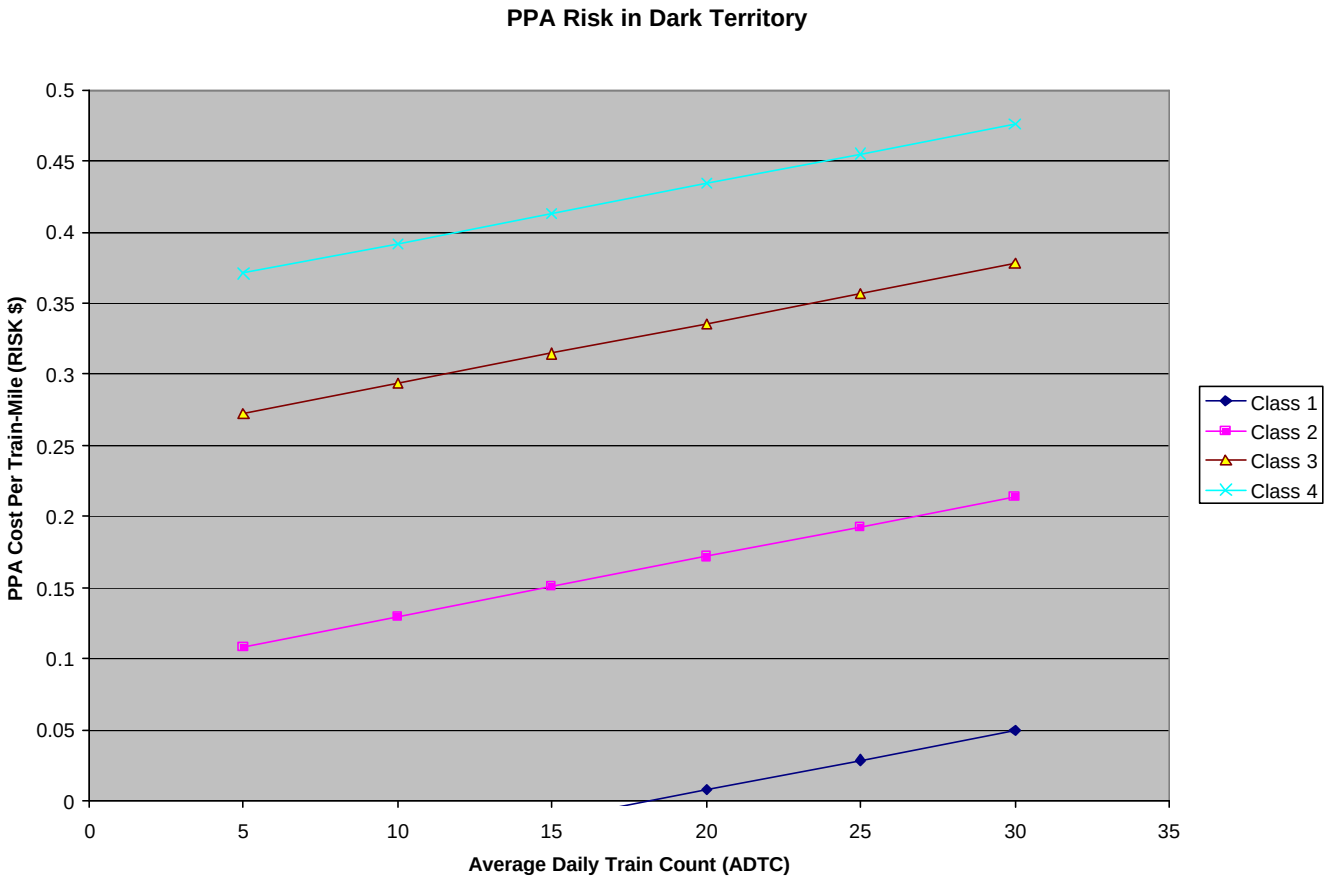


RISK/TM by ADTC for DARK

Dark Territories (Dark):

PPA Risk per Train-Mile by Average Daily Train Counts (ADTC/AADT) and by Speed Classes

RISK = 0.010928393
*(SPEED) +0.004216201
*(ADTC) -0.185856795

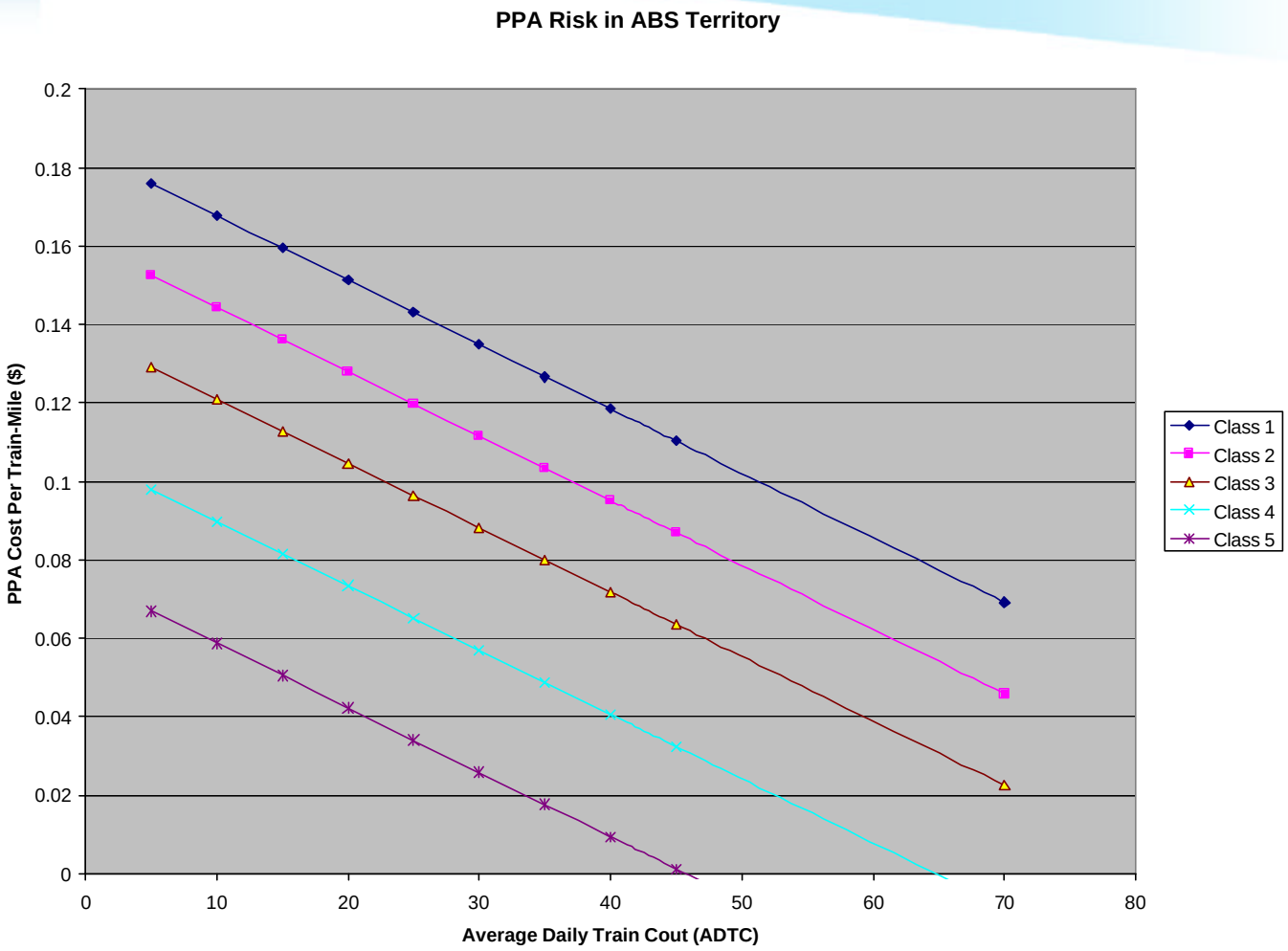


RISK/TM by ADTC for ABS

ABS Territories

PPA Risk per Train-Mile by Average Daily Train Counts (ADTC/AADT) and by Speed Classes

RISK = -0.001557018
*(SPEED) -0.001641569
*(ADTC) +0.199726113

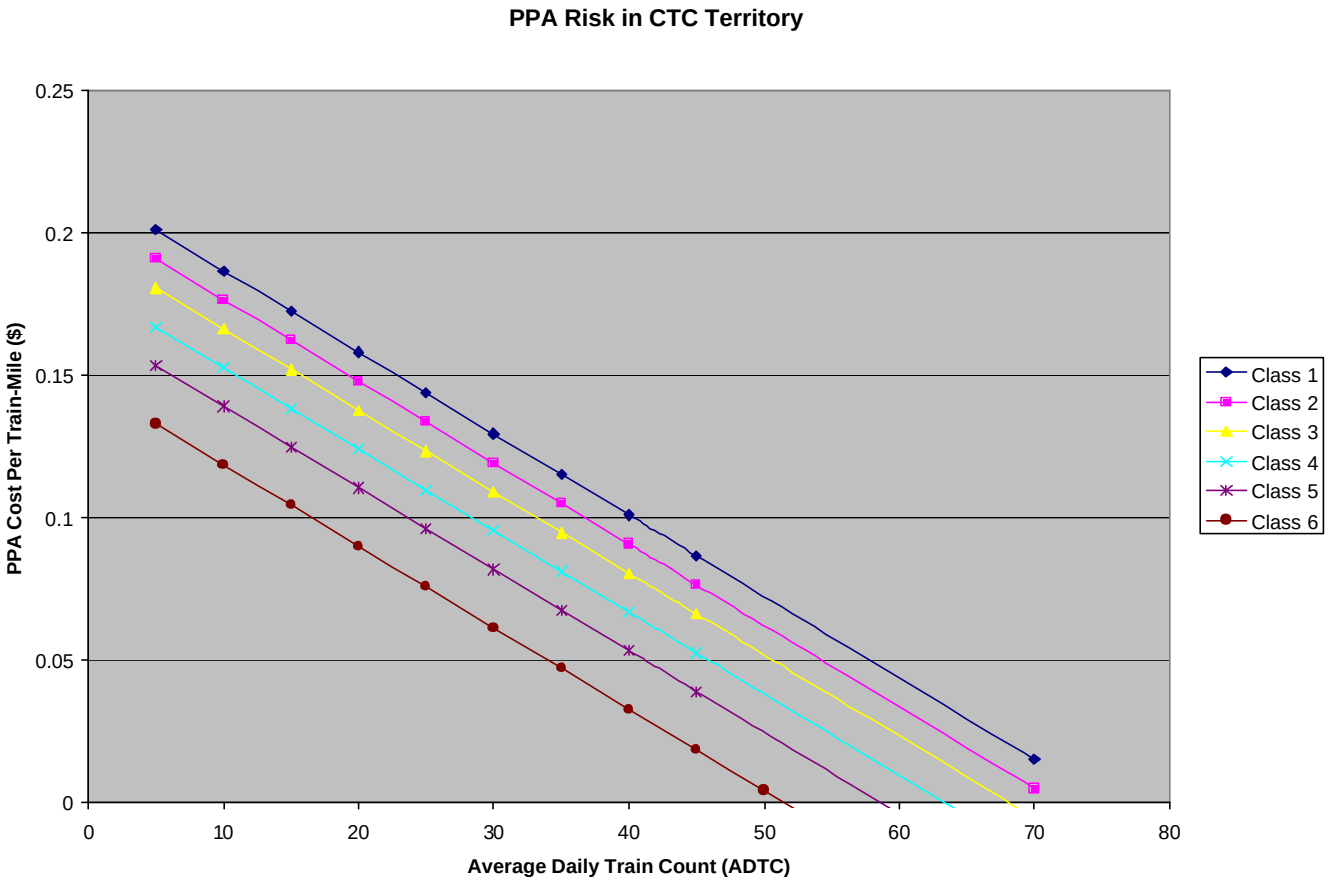


RISK/TM by ADTC for CTC

CTC Territories

PPA Risk per Train-Mile by Average Daily Train Counts (ADTC/AADT) and by Speed Classes

RISK = -0.00068044
*(SPEED) -0.002859397
*(ADTC) +0.222008449

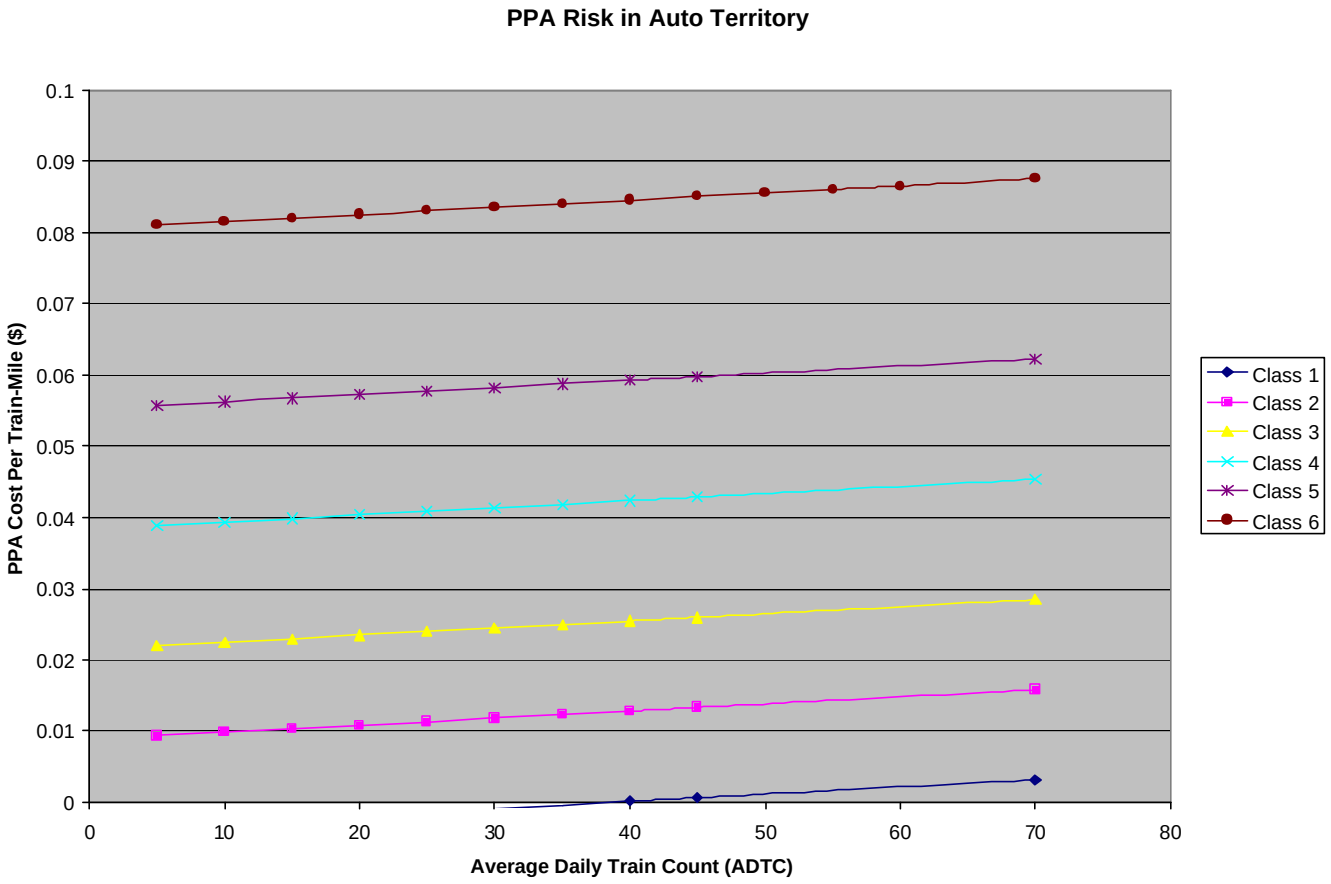


RISK/TM by ADTC for AUTO

Auto Territories

PPA Risk per Train-Mile by Average Daily Train Counts (ADTC/AADT) and by Speed Classes

RISK = 0.000843556
*(SPEED) +0.000100075
*(ADTC) -0.012263466



RISK for ALL Territory

Note:

- Linear MR Results

SPEED	Class 1	2	3	4	5	6	Mean
AADT	**10**	**25**	**40**	**60**	**80**	**110**	**45**
5	0.09054396	0.123581	0.156618	0.200668	0.244717	0.310792	0.187820082
10	0.07935832	0.112395	0.145433	0.189482	0.233532	0.299606	0.176634437
15	0.06817267	0.10121	0.134247	0.178297	0.222346	0.28842	0.165448791
20	0.05698702	0.090024	0.123061	0.167111	0.21116	0.277235	0.154263146
25	0.04580138	0.078839	0.111876	0.155925	0.199975	0.266049	0.1430775
30	0.03461573	0.067653	0.10069	0.14474	0.188789	0.254864	0.131891855
35	0.02343009	0.056467	0.089504	0.133554	0.177604	0.243678	0.12070621
40	0.01224444	0.045282	0.078319	0.122368	0.166418	0.232492	0.109520564
45	0.0010588	0.034096	0.067133	0.111183	0.155232	0.221307	0.098334919
70	-	-	0.011205	0.055254	0.099304	0.165378	0.042406692

ALL	**Slope**	**Slope**	**Intercept**	**Standard Error**	**Statistics**	**Statistics**
	a	**b**	**c**	**for RISK**	**RSQ**	**F**
Linear	0.002202478	-0.002237129	0.079704824	0.075652073	0.000153417	0.953556
Anti-Log	0.024440857	0.006153083	-1.154911256	0.014495815	0.001091675	6.791626

* The negative slope b shows that the RISK reduces when TRAIN COUNT increases.

RISK for DARK Territory

Note:

- Linear MR Results

SPEED	Class 1	2	3	4	Mean
AADT	**10**	**25**	**40**	**49**	**27**
5	-	0.108434	0.27236	0.370715	0.174004
10	-	0.129515	0.293441	0.391796	0.195085
15	-	0.150596	0.314522	0.412877	0.216166
20	0.007751	0.171677	0.335603	0.433958	0.237247
25	0.028832	0.192758	0.356684	0.455039	0.258328
30	0.049913	0.213839	0.377765	0.47612	0.279409
35	0.070994	0.23492	0.398846	0.497201	0.30049
40	0.092075	0.256001	0.419927	0.518282	0.321571
45	0.113156	0.277082	0.441008	0.539364	0.342652

DARK	Slope	Slope	Intercept	Standard Error	Statistics	Statistics
	a	b	c	for RISK	RSQ	F
Linear	0.010928393	0.004216201	-0.185856795	0.147593795	0.00141833	2.901054
Anti-Log	0.047133287	0.014023609	-1.185046394	0.02335092	0.003328463	6.82109

* The positive slopes show that the RISK increase when the SPEED or TRAIN COUNT increases.

RISK for ABS Territory

Note:

- Linear MR Results

SPEED	Class 1	2	3	4	5	Mean
AADT	**10**	**25**	**40**	**60**	**80**	**40**
5	0.175948	0.152593	0.129238	0.098097	0.066957	0.129238
10	0.16774	0.144385	0.12103	0.089889	0.058749	0.12103
15	0.159532	0.136177	0.112822	0.081681	0.050541	0.112822
20	0.151325	0.127969	0.104614	0.073474	0.042333	0.104614
25	0.143117	0.119761	0.096406	0.065266	0.034125	0.096406
30	0.134909	0.111554	0.088198	0.057058	0.025918	0.088198
35	0.126701	0.103346	0.07999	0.04885	0.01771	0.07999
40	0.118493	0.095138	0.071783	0.040642	0.009502	0.071783
45	0.110285	0.08693	0.063575	0.032434	0.001294	0.063575

ABS	Slope a	Slope b	Intercept c	Standard Error for RISK	Statistics RSQ	Statistics F
Linear	-0.001557018	-0.001641569	0.199726113	0.132761554	0.000228291	0.270472
Anti-Log	0.021806453	0.018697515	-1.161779713	0.038510449	0.001781996	2.114542

* The negative slopes show that the RISK reduces when the SPEED or TRAIN COUNT increases.

RISK for CTC Territory

Note:

- Linear MR Results

SPEED	Class 1	2	3	4	5	6	Mean
AADT	**10**	**25**	**40**	**60**	**80**	**110**	**40**
5	0.200907	0.190700	0.180494	0.166885	0.153276	0.132863	0.180494
10	0.186610	0.176403	0.166197	0.152588	0.138979	0.118566	0.166197
15	0.172313	0.162107	0.151900	0.138291	0.124682	0.104269	0.151900
20	0.158016	0.147810	0.137603	0.123994	0.110385	0.089972	0.137603
25	0.143719	0.133513	0.123306	0.109697	0.096088	0.075675	0.123306
30	0.129422	0.119216	0.109009	0.095400	0.081791	0.061378	0.109009
35	0.115125	0.104919	0.094712	0.081103	0.067494	0.047081	0.094712
40	0.100828	0.090622	0.080415	0.066806	0.053197	0.032784	0.080415
45	0.086531	0.076325	0.066118	0.052509	0.038900	0.018487	0.066118
70	0.015046	0.004840	-	-	-	-	-

CTC	Slope	Slope	Intercept	Standard Error	Statistics	Statistics
	a	**b**	**c**	**for RISK**	**RSQ**	**F**
Linear	-0.00068044	-0.002859397	0.222008449	0.141859352	0.000193601	0.540058
Anti-Log	0.013082391	0.00648483	-1.140730465	0.026333245	0.000307831	0.858805

* The negative slopes show that the RISK reduces when the SPEED or TRAIN COUNT increases.

RISK for AUTO Territory

Note:

- Linear MR Results

SPEED	Class 1	2	3	4	5	6	Mean
AADT	**10**	**25**	**40**	**60**	**80**	**110**	**45**
5	-	0.009326	0.021979	0.03885	0.055721	0.081028	0.033929502
10	-	0.009826	0.02248	0.039351	0.056222	0.081528	0.034429878
15	-	0.010327	0.02298	0.039851	0.056722	0.082029	0.034930255
20	-	0.010827	0.02348	0.040351	0.057222	0.082529	0.035430631
25	-	0.011327	0.023981	0.040852	0.057723	0.08303	0.035931007
30	-	0.011828	0.024481	0.041352	0.058223	0.08353	0.036431383
35	-	0.012328	0.024981	0.041852	0.058724	0.08403	0.036931759
40	0.000175	0.012828	0.025482	0.042353	0.059224	0.084531	0.037432135
45	0.000675	0.013329	0.025982	0.042853	0.059724	0.085031	0.037932511
70	0.003177	0.015831	0.028484	0.045355	0.062226	0.085531	0.040100808

AUTO	**Slope**	**Slope**	**Intercept**	**Standard Error**	**Statistics**	**Statistics**
	a	**b**	**c**	**for RISK**	**RSQ**	**F**
Linear	0.000843556	0.000100075	-0.012263466	0.041225219	0.003017813	0.587228
Anti-Log	0.052374975	0.030316144	-1.239669055	0.079518219	0.012152998	2.386687

* The positive slopes shows that the RISK increases when the SPEED or TRAIN COUNT increases.